

# **Environmental Impact on Fleet Tactics**

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## **LONG-TERM GOAL**

Our long-term goal is to provide an enhanced tactics prediction capability for Navy sensors and operations that accurately reflects significant environmental-acoustic phenomena. A second goal is to understand the impact of variations in water sound speed profiles (SSPs) on Modular Ocean Data Assimilation (MODAS) nowcasts. This capability is particularly relevant in shallow water areas where oceanographic, and therefore acoustic, characteristics can exhibit extreme temporal and spatial variability.

## **OBJECTIVES**

The objective of our FY00 effort was to separate, quantify, and rank order environmental effects on sonar performance and adaptive tactics. In addition, we seek to determine the required sampling density of temperature profiles to achieve a useful 3-D MODAS field.

## **APPROACH**

During FY00, we focused on scientific discoveries regarding the impact of the littoral environment on real Fleet operations. Our approach is to use high-spatial density AXBT temperature data from the Sea of Japan in summer and winter to establish "ground-truth" environments and then from sub-sampled data determine the required sampling density to achieve a desired minimum error field.

## **WORK COMPLETED**

This year's major accomplishments include: (1) processing the AXBT data and quantifying errors in MODAS fields; and (2) field testing the latest version of our environmentally-sensitive search planning algorithms during the SHAREM 134 exercise, held in August 2000, in the East China Sea.

## **RESULTS**

### **Determining Required Sampling Density**

During SHAREM 126 (September 1998) and SHAREM 127 (February-March 1999) in the same area of the Sea of Japan off Korea, 214 temperature profiles were obtained with SSQ-36's (air deployed expendable bathythermographs or AXBTs). Five grid resolutions were obtained: two during SHAREM 126 and three during SHAREM 127.

The optimal ocean assimilation and interpolation package known as MODAS was used to examine the effects of sampling density on accuracy of the resulting sound speed field. MODAS was also used to create sound speed profiles from the input temperature profiles by use of its internal salinity database. Optimal interpolation requires an initial base field or "first guess" field. The initial first-guess field for each day was constructed using the full-featured MODAS package referred to as "MODAS-Heavy" plus the MODAS regional climatology and satellite-derived sea surface temperature. The "true" or baseline interpolated sound speed field was constructed with the basic MODAS system, "MODAS-Lite," by assimilating all AXBTs (approx. 45) from each day into the first-guess field for that day. The effect of reduced sampling density was quantified by creating additional interpolated fields with varying subsets of the AXBTs available from each day and examining the differences between the subset fields and the baseline fields. Subsets of profiles were chosen such that the average distance between profiles used in the analysis was as constant as possible. The analyses were confined to the upper 300 m because the depth specification for the A/N SSQ-36 is 305 m and because most of the ocean variability in this region is above 300 m.

The subset fields that were created for comparison were:

1. MODAS-Lite assimilation of half of the AXBTs from each of the five days (denoted CLSTHLF on the accompanying figures) (average separation of 19.1 nmi)
2. MODAS-Lite assimilation of a quarter of the AXBTs from each of the five days (denoted CLSTQTR) (average separation of 29.6 nmi)
3. MODAS-Lite assimilation of six of the AXBTs from each of the five days (2 different sets of 6 profiles each day, denoted CLST6\_1 and CLST6\_2) (average separation of 44.1 nmi)
4. MODAS-Lite assimilation of four of the AXBTs from each of the five days (2 different sets of 4 profiles, denoted CLST4\_1 and CLS4\_2) (average separation of 57.1 nmi)
5. MODAS-Lite assimilation of three of the AXBTs from each of the five days (3 different sets of 3 profiles, denoted CLST3\_1 through \_3) (average separation of 59.9 nmi)

An example summary of the results for one day, 7 September 1998, is given in Fig. 1. The results are measurement-density dependent. Differences between the baseline field and measured subset fields generally decrease as the sampling density increases. The resulting fields are usually an improvement over simple climatology even when satellite-derived sea surface temperature (SST) are included. However, at low measurement densities (CLST3 and 4) the differences between the baseline and measured subset fields are as large as those between the baseline and climatology (and climatology + SST) fields. This is particularly true in the depth range of 75 to 175 m (not shown), where, in some cases, an under-sampled measurement field fails to improve the overall sound speed field estimate at all.

The general pattern found for the 7 September data hold for the other datasets, as well. The findings for all days are summarized in Figs. 2 and 3. In Fig. 2, upper panel, we see that the mean RMS sound speed difference declines as the density of AXBTs (or TAM buoys) increases. A density of 0 AXBTs per 10,000 nmi<sup>2</sup> yields the first guess field of MODAS climatology plus satellite SST. A density of 21 corresponds to the MODAS field produced by assimilating a regular grid of sound speed profiles, with measurement locations 19 nmi apart (i.e. every other AXBT profile on each day). Baseline vs. Climatology + SST, has a higher mean RMS error than any of the other comparisons. The mean RMS

difference declines from a maximum of 6 to 7.5 m/s for climatology + SST alone, to a minimum of 1.5 to 2 m/s for the highest AXBT density. One might conclude that using any additional data to augment the Climatology + SST would be better than none at all.

However, the danger in this rule of thumb is illustrated by the lower panel in Fig. 2. At densities of 3 and 4 buoys per 10,000 nm<sup>2</sup> (corresponding to subsets containing 3 and 4 profiles each), the maximum sound speed differences can exceed those from climatology + SST alone. Comparing the climatology + SST fields with the baseline fields for each day gave maximum sound speed differences of about 24 - 28 m/s, while the maximum differences with the two lowest density fields ranged from about 23 - 34 m/s. At increasingly higher densities, however, the maximum sound speed errors became less than those of climatology + SST. At the highest density of about 21 profiles per 10,000 nmi<sup>2</sup> the maximum sound speed differences declined to about 11.5 - 16 m/s.

The relationship between mean RMS sound speed difference and maximum sound speed difference is approximately linear (Fig. 3). As a result, we can determine the approximate sampling density needed for a specified maximum sound speed error or for a specified mean RMS sound speed difference. For example, if we wish to obtain a RMS sound speed difference between the true and sampled field of 5 m/s or less, we see from Fig. 2 that the required sampling density is about 7 or 8 profiles per 10,000 nmi<sup>2</sup>. This corresponds to an average spacing on the order of 40 nmi. From Fig. 3 we see that the maximum sound speed error in the water column for this specified RMS difference would be on the order of 23 or 24 m/s.

The particular numerical values we have found for these data cannot a priori be said to apply to other regions and times, but the technique we have outlined may be applied anywhere that suitable data exists. One conclusion is that obtaining only a little bit of data may not be cost effective compared with simple climatology or climatology plus satellite-derived sea surface temperature. A certain minimum sampling density seems to be required to make any sampling at all worthwhile. Further similar analyses should be done in different regions and times to see if this is a robust conclusion and if a generic break-even point can be specified.

## **IMPACT / APPLICATIONS**

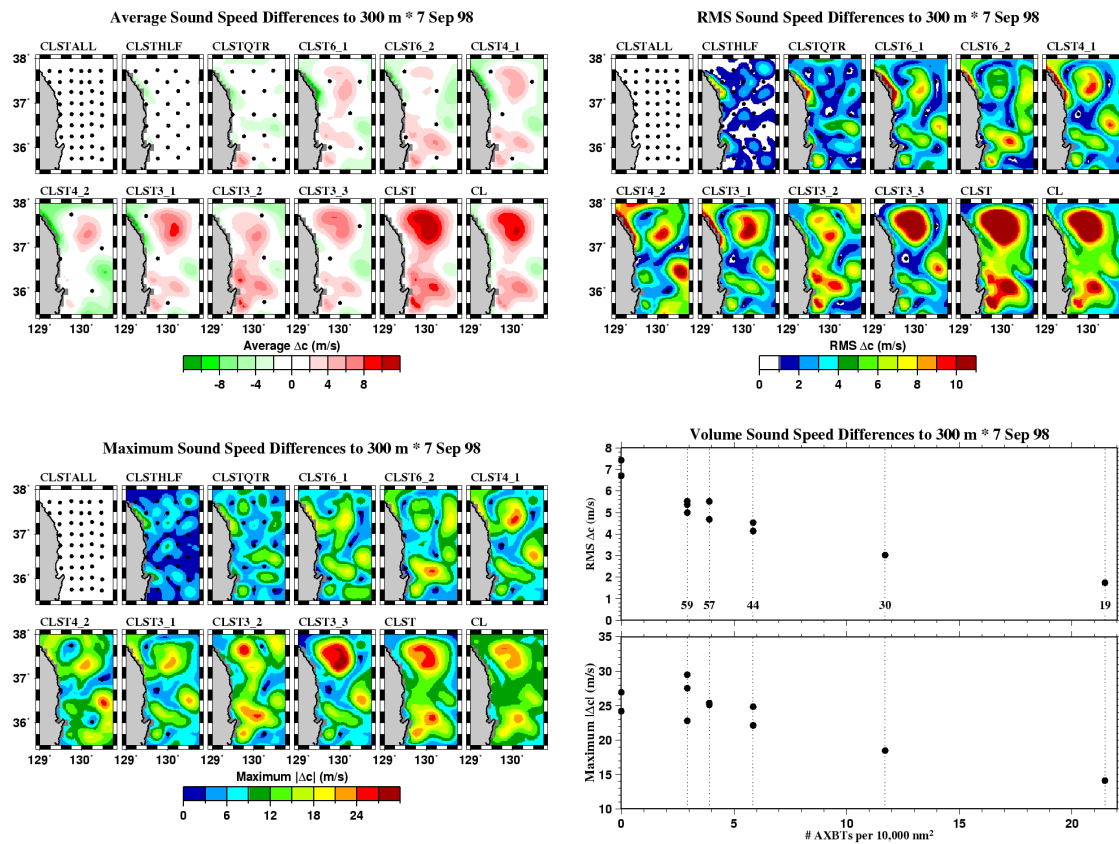
Development of a tactical search optimization tool that maximizes use of MODAS information will provide valuable guidance in performance assessment and mission planning for antisubmarine and mine warfare activities.

## **TRANSITIONS**

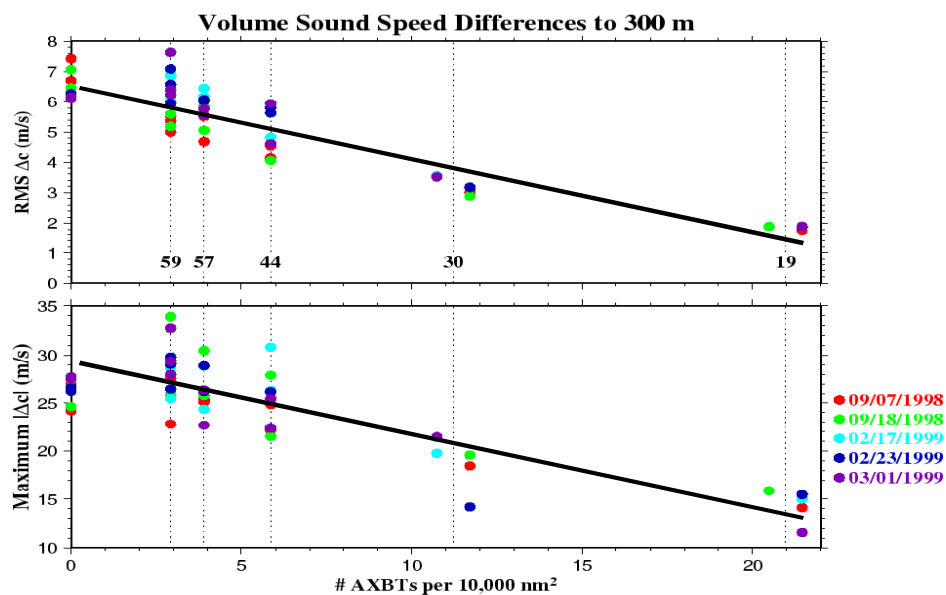
Although transition of the present effort is pending, we envision the product to be integrated with CADRT and it is being considered for inclusion in the APB (T) process for submarine use. There are many other potential spin-off transitions, including the LBVDS and MACE programs.

## **RELATED PROJECTS**

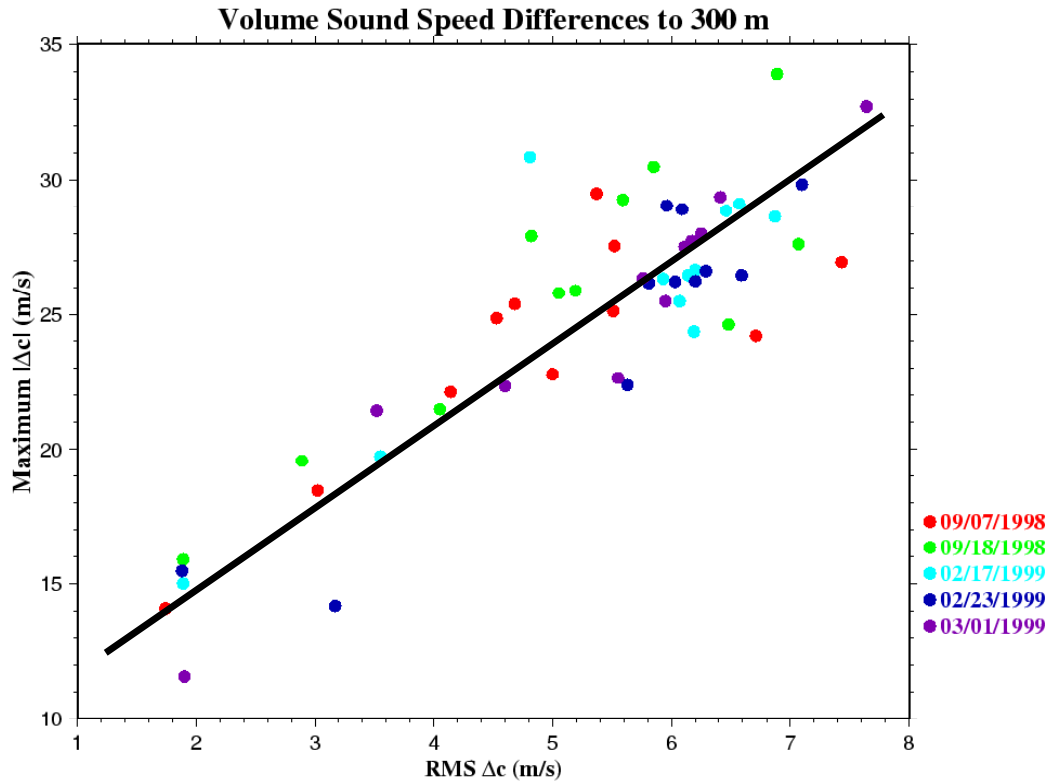
The present effort is related to other Tactical Decision Aids (TDAs) such as the Sonar In-Situ Mode Assessment System (SIMAS), Tactical Control Program (TCP), and ASPECT. It is also related to the IMAT program whose training features can be used to make tactical decisions.



**Figure 1.** Average, RMS, and maximum sound speed differences between the surface and 300 m for the 7 September 1998 dataset. All differences were taken between the MODAS analysis using all AXBTs from that day and analyses constructed using various subsets of the data.



**Figure 2.** Summary of the total volumetric RMS (upper) and the maximum (lower) sound speed differences for all analyses and datasets. The dark lines are the approximate best-fit linear relationships between the error parameters and the density of AXBT (or TAM) profiles.



*Figure 3. Maximum sound speed differences versus volumetric RMS sound speed differences for all the MODAS analyses. The solid straight line is the approximate best fit to the data.*

## REFERENCES

“Software Test Description for the Modular Ocean Data Assimilation System (MODAS),” Naval Oceanographic Office, 1996.

## PUBLICATIONS

H. Chandler, D. del Balzo, J. Mobbs, M. Collins, J. Leclere, L. Pflug, "GRASP - Genetic Range-Dependent Algorithm for Search Planning," NRL report NRL/FR/7180—99-9698 (submitted.)

<http://www7180.nrlssc.navy.mil/homepages/GRASP/GRASP.html>